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TDMA Based Reader Anti-Collision Algorithm for Cluster Based Dense RFID Networks Using Particle Swarm Optimization Approach

[1]C. Hema, [2]DR. Sharmila Sankar and [3]DR. M. Sandhya

[1]*Assistant Professor, Department of Computer science and Engineering, B.S.Abdur Rahman University, C.Hema, Chennai 600048, TamilNadu, India.*
[2]*Head of the Department, Computer science and Engineering, B.S.Abdur Rahman University, Dr.Sharmila Sankar, Chennai 600048, TamilNadu, India.*
[3]*Professor, Department of Computer science and Engineering, B.S.Abdur Rahman University, Dr.M.Sandhya, Chennai 600048, TamilNadu, India.*

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ABSTRACT

This paper proposes cluster based RFID Network framework model to mitigate the RFID Reader Collision Problem in dense RFID networks. It consists of three stages such as cluster head selection scheme, cluster formation scheme and scheduling mechanism. We introduced the particle swarm optimization approach based clustering. The main idea in our approach is to generate energy aware cluster by optimal selection of cluster heads. The cluster head sets up a TDMA based anti-collision algorithm for its cluster members to avoid Collisions among readers. Cluster head constructs the reservation table for its cluster members. Based on that, the temporal cluster header organizes the cluster members to read tags in their own reading range respectively. The cluster-based particle swarm optimization approach improves the life time of RFID Network and also reduces reader collision by generating energy efficiency cluster.

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INTRODUCTION

RFID (Radio-Frequency Identification) refers to a system that will transmits the identity (in the form of a unique serial number) of any object wirelessly, with the help of radio waves. This is also called as contact-less technology and **d**edicated **s**hort **r**ange **c**ommunication (DSRC). A typical RFID system consists of three components: tags, transceiver (reader) and the host computer system to process the information.

Usually readers transmit signals to their tags for the verification of the data information stored. Tags are normally attached on to objects and they transmit the object-related information to readers as requested.

Instead of using light to or read a number from a given bar code, radio waves can be used to read and identify a number from the RFID tags. RFID therefore RFID eliminates the need for line-of-sight reading that bar coding depends on. Usage of radio signal means that the tag no longer has to be visible on the object to which it is being attached; the tag can be hidden inside the item or box that is to be identified and still be read. This reduces the manpower as a person need not give the tag to the reader and it can simply be fixed to a wall for example. As the reader crosses the item, it will automatically read the data, thus enhancing potentially a large savings in labor costs as well as substantially increase the throughput of scanned items.

Another advantage of RFID is its ability to read multiple tags all together at once. Unlike barcodes, it is not necessary to scan each tag to the reader individually, instead all the tags within the range of the reader can be read almost simultaneously as they pass the reader. Again, this leads to potential savings in not having to manually present the reader to each item to be identified.

Furthermore, tags can also be read/write where specific data can also be written to the tag if required, a feature not possible by the barcode system. This feature has a very extended range of use in for IT systems and it is the greatest benefit of RFID.

Mobile RFID (M-RFID) is the technology that provides information about objects equipped with an RFID tag over a telecommunication network. Any mobile device such as a mobile phone can be used to install the reader. Unlike the stationary RFID, in the mobile RFID, readers are mobile and the tags are fixed. The advantages of M-RFID over RFID is the

Corresponding Author: C. Hema, Assistant Professor, Department of Computer Science and Engineering, B.S.Abdur Rahman University, C.Hema, Chennai 600048, TamilNadu, India.
Tel: +91 8678917864; E-mail: hemathanam@gmail.com

wireless connectivity and the ability of a small number of mobile readers of greater area coverage than a number of fixed readers. Customers having mobile phones with an RFID reader installed in it will be able to scan products to retrieve or transmit information. The aim is to support supply chain management. This has also found its way in commerce and is used in e-shopping, payments, advertising, transportation and logistics.

In a typical Mobile RFID environment, there are generally two collision problems that reduces read throughput (number of tags read per unit time)

Tag collision:

It occurs when more than one tag responds to a reader and the reader fails to identify the signals from the corresponding tags.

Reader Collision:

In M-RFID, Certain applications need multiple readers to function in close proximity of each other. Due to this reason, the signals from one reader might overlaps with the signals from the other readers. Such interference is called reader collision.

There are two classification type of reader collision:
1) Multiple reader to tag collision:

Multiple reader to tag collision occurs when one tag is attempted to be read by multiple readers simultaneously.

Reader to reader collision:

Reader to reader collision occurs when a strong signal from a reader overlapses with a weakly transmitted signal from a tag.

Reader Collision leads lack of communication between the readers and some tags, inefficient and incorrect operation of a RFID system.

When readers are mobile and they are densely distriFbuted, reader collision becomes inevitable.Therefore, developing ways to manage the increasing number of readers without interference or overlapping from neighboring readers is very essential.

Thus, in this paper, we introduce the cluster-based approach to maximize the life time of RFID Network and reduce reader collision. The Cluster based RFID system uses particle swarm optimization approach for generating energy aware clusters by optimal selection of cluster heads. The PSO eventually decreases the cost of locating optimal selection of cluster heads and also proposes an efficient reader anti-collision algorithm, namely, TDMA based reader anti-collision algorithm, which uses cluster head in dense RFID networks with mobile readers. This algorithm improves the efficiency of reader operations by allowing them to work without interference from neighboring readers. In addition, all readers are controlled by the cluster head.

In a clustering design method, readers are classified into various clusters with different assignment levels. The cluster head is responsible for data aggregation. Data aggregation is the technique by which data is aggregated from many readers to eliminate redundant data and provide combined data to the BS. This is an important way for the RFID Networks to manage energy consumption efficiently.

In clustering scheme, data aggregation helps to reduce transmission data and saves energy. Moreover, intra-cluster and inter-cluster communications can minimize the count of RFID readers performing long distance communications, thus enabling less energy consumption for the entire network. In addition, the task of data transmission is done only by CHs in clustering scheme, which is again very energy efficient.

In this paper, we have considered one such swarm intelligence mechanism known as Particle Swarm Optimization algorithm (abbreviated as PSO). PSO is a novel population-based stochastic search algorithm and it is an alternative solution to the complex non-linear optimization problem and its logic was originally inspired by simulation of the social behavior of animals such as bird flocking, fish schooling and so on. Process called group communication acts as the basis. According to the concept of group communication, the sharing of individual knowledge when a group of birds or insects searching for food or migrating, and so forth in a search, although all birds or insects do not know where exactly the best position is. But from the nature of the social behavior, if any member does find a desirable path or way, the rest of the members of the group will follow automatically.

The PSO algorithm is derived from animal’s nature to solve optimization problems. In PSO, each member of the population is called a particle and the population is called a swarm. Beginning with a randomly initialized population and moving in randomly chosen directions, each particle travels through searching space and remembers the best previous positions of itself and its neighbors. Particles of a swarm communicate desirable positions among them as well as dynamically adapt to their own position and velocity derived from the best position of all particles. The next step starts when all the particles move. Finally, all the particles tend to move towards better and more desirable positions over the searching process until the swarm reach a destination close to an optimum of the fitness function. The PSO method is becoming famous because of its simplicity and ease of implementation and also because of its ability to quickly converge to a good solution. It does not demand gradient data of the functions to be optimized and makes use of primitive mathematical operators only.

On a comparison with other optimization methods, it is quick, cheaper and more efficient. In addition, there are few parameters to adjust in PSO.

That's why PSO is an ideal and the best optimization problem solver in optimization problems. PSO is well suited to solve the non-convex, non-linear, discrete, continuous, integer variable type problems.

The Outline of this paper is organized as follows: existing reader anti-collision algorithms for mobile RFID are reviewed in Section 2, and a Cluster Head Selection and Cluster Formation are explored in Section 3. In Section 4, the proposed algorithm is explained with the mathematical analysis of the algorithm and conclusion is provided in Section 5.

Related work:

The already in use RCP solutions can be further classified into three categories: scheduling based schemes, coverage based schemes and control mechanism based schemes. The concept of the scheduling based algorithms is to allocate available resources, slots and frequencies, to all the readers accordingly, in order to avoid multiple readers transmitting in a same frequency and at the same time. This type includes Color wave NFAR, CDCIP, DRA etc.

Color wave is a distributed TDMA based algorithm, where in each unique new reader selects any time slot (color) randomly and read its tag in its own allocated time slot. If a reader selects a time slot that is the same as that of other neighbor readers and then reader collision occurs, reader will select another new timeslot and send 'kick' messages to the neighbors to let them know the new available time slot. Colorwave is generally not apt for the use in mobile RFID because TDMA scheduling needs reader synchronization and therefore high mobility will generate lots of communication overhead for scheduling.

Jun-Bong Eom *et al* proposed an efficient Neighbor Friendly Reader Anti-collision (NFRA) algorithm using a polling server in dense and dynamic RFID networks with mobile readers. The readers can overlook and quickly decide whether they can work or not without interfering neighboring readers with help of the server and can be easily synchronized to minimize the reader collision. The goal of NFRA is to enable maximum number of readers to work without interfering with one another. It can solve the synchronization problem of DCS and Colorwave and it does not require much of computational load as in the Qserver of HiQ.

Juyi Qiao *et al* presented Code Division Cooperative Identification Protocol (CDCIP), which is a CDMA, based centralized reader anti-collision protocol, In this protocol temporal cluster heads are generated by the cluster head election. Code words are allocated to all the readers in the cluster uniquely. The temporal cluster heads determine which tags involving identification are reserved to particular header which belongs to the cluster.Finaly, all the readers initiate read the tags almost simultaneously or what can be said as, in a parallel manner, at the same time.

Jianwei Wang *et al* proposed a novel anti-collision Protocol, DRA (Distributed Reservation based Anti-collision protocol) to cut down on the reader collision problem in multiple reader RFID Systems. The DRA protocol divides the communication process in mobile reader RFID System into three steps. First step, Based on CSMA scheme, a temporal cluster head is only selected from adjacent immediate readers interfered with each other. Second one, the temporal cluster heads reserve and allocate the reading sequence of the readers within its cluster. Third one, cluster members are coordinated to work without interference from neighboring readers. Compared with Pulse protocol, the drop of beacon channel in DRA helps to reduce the communication overhead very significantly.

Zhaohao Wang *et al* proposed a reader anti-collision protocol called Priority Cluster Protocol (PCP) to mitigate and to put a tab on the reader collision problem. Based on PCP, Clusters are made and constructed dynamically by the readers. Every reader in cluster is given priority to read tags in sequence without collision. The two stages are introduced in order to obtain better performance. In the first stage, communication sequence of readers in the cluster is optimized further to minimize the delay. In the second stage, readers outside the cluster are given chance to read the tags randomly when channel is idle at temporary state.

The Control mechanism-based algorithms transmit announcement control signal, such as beacon signal, to mitigate the reader collision problem. When a reader is reading tags, it will broadcast control signal to other readers. The reader receiving the control signal will wait for the next round to communicate with tags. This type includes Pulse , TPDM etc.

Birari *et al* suggested a pulse distributed protocol based on beaconing mechanisms. While a reader is reading the tags, it then as time goes on broadcasts a beacon on a separate unique control channel. Any reader that wants to establish communication, communicate with tags, first senses the control channel for a beacon. If it does not receive any beacon and starts communicating with the tags. It continues to periodically transmit a beacon as long as it is communicating with tags. But it wastes the channel capacity in multipath environments.

Kwangcheol Shin *et al* proposed a new concept model of a reader collision problem between adjacent channel and then introduced a novel reader anti-collision algorithm for RFID readers that use many multiple channels. To deflect such interference with the adjacent channels, the then suggested algorithm separates data channels into odd and even numbered channels and allocates odd numbered channels first to readers. It also sets an empty unused channel between the control channel and the data channel to ensure that the control messages and the signal of the adjacent channel does not occur.

Two phase dynamic modulation [TPDM] protocol, which aims to reduce reader collision problems, efficiently perform communication in high mobility RFID Networks. TPDM consists of following two scheduling phases follows :1) Region scheduling phase., 2) Hidden terminal scheduling phase. In the first phase, reader who wants to read with tag will first detect the density in its area by transmitting beacon signal through the control channel. Based on the information of the neighboring density, an appropriate back off time will be issued adaptively for scheduling. In the hidden terminal scheduling phase, the scheduling will be performed for tangible communications between readers.

The coverage-based algorithms modifies dynamically to reduce the overlapped area between the adjacent readers as much as possible, but it usually needs a central node to calculate the distance between every two readers and adjust their reading ranges. This type includes LLCR.What the Low Energy Localized Clustering for Homogeneous or Heterogeneous RFID Networks(LLCR) does precisely is minimize the overlapping areas of clusters by regulating the radius of clusters that each RFID reader covers. According to objective function of LLCR, Energy aware radius for each cluster is computed. The LLCR consists of two stages namely, initial stage and cluster radius control stage.

Proposed Framework:

Our goal is to mitigate the RFID Reader Collision Problem, we propose cluster based RFID Network framework model, which will also help the RFID Network to improve the energy efficiency and read rate. It consists of cluster head selection scheme, cluster formation scheme and scheduling mechanism in the cluster. The Cluster based algorithm uses particle swarm optimization approach for generating energy aware cluster by optimal selection of cluster heads. Cluster heads run the TDMA based reader anti-collision algorithm to schedule the all readers in the cluster to work without interference from neighboring readers.

Cluster head selection scheme using PSO:

The operation of our protocol is based on a centralized control algorithm that is implemented at the server side, which is an anode with a large amount of energy supply. The proposed protocol operates and functions in rounds, where in each round begins with an arrangement phase at which cluster heads are selected and clusters are formed. At the starting of each arrangement phase, all RFID Readers send information about their current energy status and locations to the base station (server). Based on this information, the base station computes the average energy level of all Readers. To guarantee that only readers with a sufficient energy are selected as cluster heads, the readers with an energy level above the average are eligible to be a cluster head candidate for this round. Next, the server (base station) runs the PSO algorithm to determine the best K cluster heads that can minimize the cost function, as described by equation (1)

$$\cos t = \beta \times f_1 + (1-\beta) \times f_2 \text{......................} (1)$$

Where the constant β is a user defined constant used to weigh the contribution of each of the sub-objectives. f1 is the maximum average Euclidean distance of nodes to their associated cluster heads and f2 is the ratio of total initial energy of all nodes to the total energy of the cluster-head candidates. These are expressed as equations (2) and (3) respectively

$$f_1 = max_{k=1,2,\ldots,K} \left\{ \sum_{\forall n_i \in C_{p,k}} d\left(n_i, CH_{p,k}\right) / \left|C_{p,k}\right| \right\}. (2)$$

$$f_2 = \sum_{i=1}^{N} E(n_i) \; / \sum_{k=1}^{K} (CH_{p,k}) \text{......................} (3)$$

Here, N is the number of readers out of which K will be elected as the cluster-heads. jCp;kj is the number of readers that belong to cluster Ck in particle p. This guarantees that only the readers that have above average energy resources are elected as the cluster-heads, and that the average distance between the readers and the cluster-heads is minimum. The cost function described above has the intention of concurrently reducing the intra-cluster distance between readers and their cluster heads, as enumerated by f1; and also of optimizing the energy efficiency of the network as enumerated by f2. According to the cost function described above, a small value of f1and f2 recommends dense clusters with the optimum collection of readers that have sufficient energy to perform the cluster head tasks during the cluster setup phase

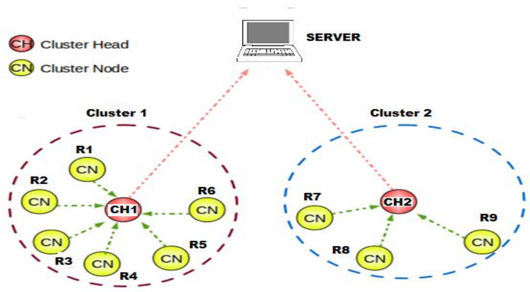

Fig. 1: Cluster Head Selection and Formation.

Cluster formation:

Fig. 2 shows the flowchart of PSO algorithm applied

For a RFID network with *N* readers and *K* predetermined number of clusters, the network can be clustered as follows.Assume a network with N readers with K predetermined number of clusters, the network can be clustered as follows.

1. Let K be the randomly selected cluster heads among the eligible cluster head candidates to initialize S particles

2. The Cost function is evaluated
a. For each node *ni*, *i* = 1,2,…,*N*
- The distance d(ni,CHp,k) between all cluster heads CHp,k and node ni is determined .
Then node ni is assigned to cluster head CHp,k.
b. Evaluate the function using equations (2) and (3).
3. For each particle, calculate the personal and global best value
4. The particle's velocity and position is updated using(1)
5. Limit the change in the particle's position value
6. Now the closest (x,y) coordinates is mapped with the new updated position
7. Repeat steps 2 the maximum number of iterations is reached

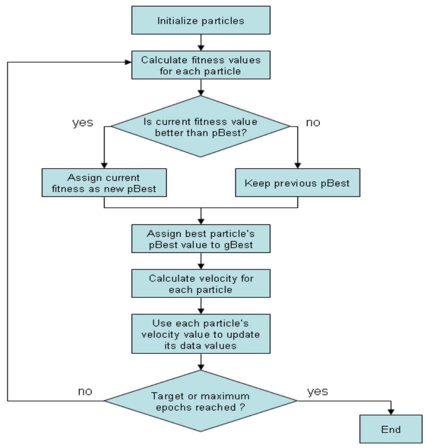

Fig. 2: Flow diagram illustrating the particle swarm optimization algorithm.

After the base station has identified the optimal set of cluster heads and their associated cluster members, the base station transmits the information that contains the cluster head ID for each reader back to all readers in the RFID network and then cluster head operate as a local control centre to coordinate and schedule the all readers in its cluster. To reserve and organize the communication sequence of the readers within its cluster, we used a similar approach as that used in DRA (Distributed Reservation-based Anti-collision) protocol [2], where the temporal cluster heads reserve and organize the reading sequence of the readers within its cluster. Based on the reserved reading sequence, Cluster members are scheduled to work without interference from neighboring readers.

TDMA based reader anti-collision algorithm:

The cluster head sets up a TDMA based anti-collision algorithm for its cluster members to avoid Collisions among readers. In TDMA based reader anti-collision algorithm, to reduce the reader Cluster head divides a frame into several time slots and reader reads the tags using one of these timeslot in a frame. The intention of the TDMA based anti-collision algorithm is to reserve the reading sequence under the control of temporal cluster headers. From the point of view of RFID, to solve RCP, TDMA (Time Division Multiple Access) is a reasonable option comparing to FDMA (Frequency Division Multiple Access) and CDMA (Code Division Multiple Access).

The communication sequence process of TDMA based anti-collision algorithm is implemented as follows:
1. Initially the temporal cluster header notifies the slave readers in the cluster to send out the reservation requests, the collection of the reservation sequence number is [1~Nr] by transmits a commence signal
2. While the slave readers get the signal from the cluster header, Cluster members select a number Si ∈ [1~Nr] as its sequence number and sends reservation request in turn to the cluster header at the Sith reservation slot.
3. The collision results of all the reservation slots are checked by the temporal header which creates a reading sequence reservation table for the cluster members.

Based on the reservation sequence table, the cluster header organizes the cluster members to read tags in their own reading range respectively. In collision-less reading process, the temporal header transmits signal to the slave readers to activate the reading process in the reserved order. After the cluster members read the tags in its range, an acknowledgement signal is sent back to the temporal cluster header to denote its reading termination. Then the temporal cluster header notifies the next reader on the reading sequence reservation table to read tags. After all the slave readers in the cluster complete their tag-reading procedure based on the reading sequence reservation table, the above three steps are repeated by the temporal cluster head until all the slave readers in the cluster accomplishes their tag-reading process.

Simulation Results:

The proposed reader anti-collision algorithm is used to analyse and compare various performance. MATLAB is used to evaluate the performance of 100 readers. The interrogation range of the reader is 10m, interference range of the reader is 25m.The performance improvement is studied in terms of Bit Error Rate (BER) and Signal to Noise Ratio (SNR). Table.1 shows the shows the performance improvement in terms of SNR of Reader after implementing anti-collision approach:

The results indicate that SNR has increased thereby showing considerable performance improvement. Table 2. shows the performance improvement observed in terms of BER.

It can be seen that BER has reduced considerably as the interference errors have reduced due to the implementation of anti-collision algorithm.

Table 1: SNR Comparison.

Reader	SNR- Pre Anti-collision	SNR- Post Anti-collision
R1	116.28	147.06
R2	157.89	206.90
R3	119.05	156.25
R4	125.00	153.85
R5	121.95	172.41
R6	162.16	250.00

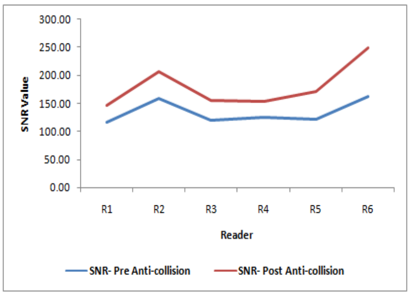

Fig. 2: shows the performance graph corresponding to the values listed in the above table.

Table 2: BER Comparison.

Reader	BER- Pre Anti-collision	BER- Post Anti-collision
R1	0.016	0.008
R2	0.014	0.004
R3	0.021	0.011
R4	0.017	0.007
R5	0.013	0.008
R6	0.018	0.006

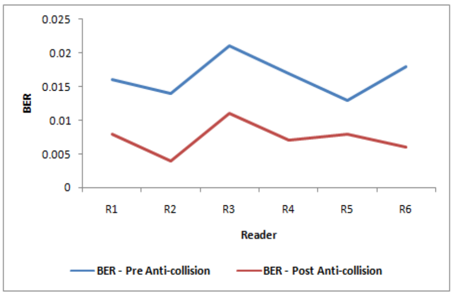

Fig. 3: Shows the performance graph corresponding to the BER table.

Conclusion:

The various algorithms published in previous research works were not yielding better results to reduce the reader collision in high density, mobile RFID network. The cluster-based particle swarm optimization approach improves the life time of RFID Network and also reduces reader collision by generating energy efficiency cluster. TDMA based reader anti-collision algorithm improves the efficiency of reader operation by scheduling all the readers in the cluster to work without interference from the neighboring readers. The performance improvement after implementing the anti-collision algorithm has been measured and reported in terms of Signal to Noise Ratio and Bit Error Rate. Results indicated that the collision rate has decreased considerably due to the increase in Signal to Noise Ratio and reduction in Bit Error Rate value.

Future Work:

Future work will be focused in the direction towards enhancing the proposed approach to include various other performance parameters into consideration and also towards scaling the approach to more clusters. Also, the study can be carried out by extending the network configuration changes and exploring possibilities of enhancing the performance further.

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